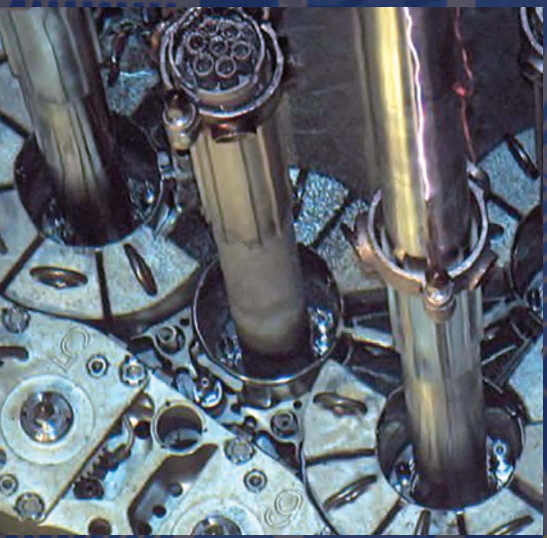
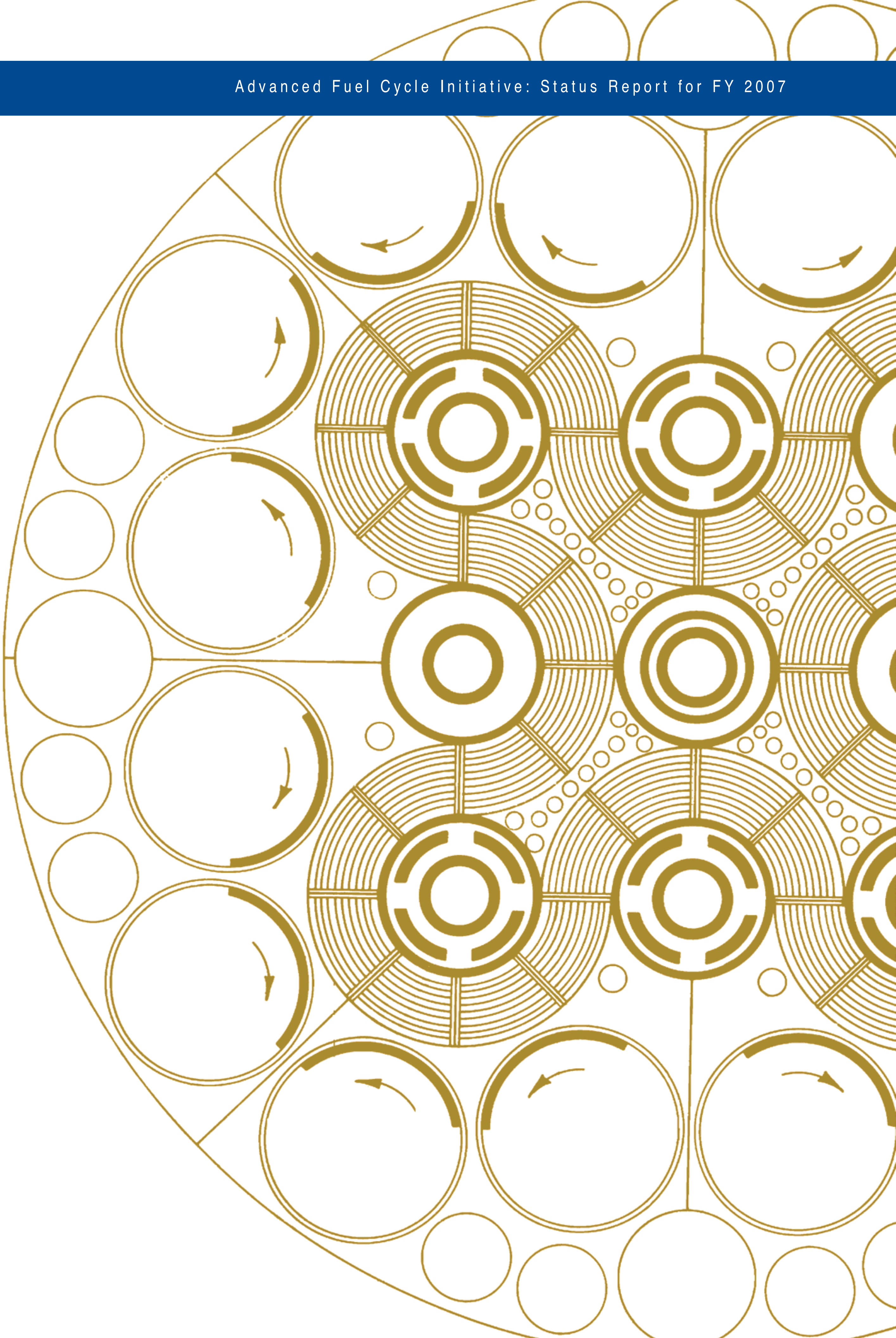
GNEP-TIO-PMO-PM-RP-2008-000040, Rev. 0

U.S. Department of Energy
Office of Nuclear Energy
Office of Fuel Cycle Management



Report to Congress Advanced Fuel Cycle Initiative: Status Report for FY 2007

February 2008



Advanced Fuel Cycle Initiative: Status Report for FY 2007

Executive Summary

The mission of AFCI is to develop fuel cycle technologies that will support the economic and sustained production of nuclear energy while minimizing waste and satisfying requirements for a controlled, proliferation-resistant nuclear materials management system.

The Department of Energy (DOE), Office of Nuclear Energy has prepared this report in response to requirements in the Energy Policy Act of 2005 that directs the Secretary of Energy to submit an annual report to Congress on activities of the Advanced Fuel Cycle Initiative (AFCI).

The mission of AFCI is to develop fuel cycle technologies that will support the economic and sustained production of nuclear energy while minimizing waste and satisfying requirements for a controlled, proliferation-resistant nuclear materials management system. The program is focused on implementing the Global Nuclear Energy Partnership (GNEP), which is DOE's comprehensive initiative that supports the safe, secure expansion of nuclear power both internationally and domestically. AFCI is the main domestic component of the broader, international GNEP. The program is supported by fuel cycle research performed at ten national laboratories, dozens of universities located across the country, and our international collaborators' laboratories.

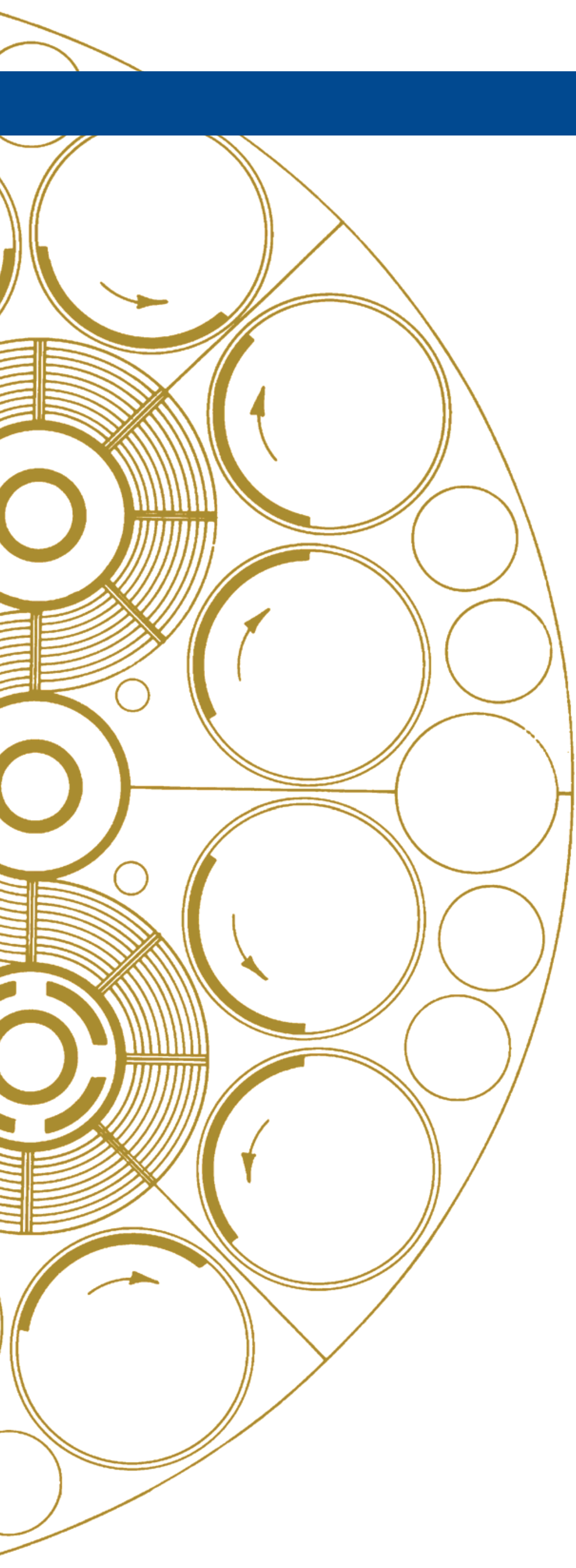
This report discusses FY 2007 research accomplishments associated with the major elements of the AFCI Program. The program's elements include Systems Analysis, Separations Technology Development, Advanced Fuels Development, Transmutation Engineering, Transmutation Education, and Fuel Cycle Facilities.

The program achieved success in a wide range of research areas during the year. Some of the most significant accomplishments discussed in the report include:

- Creation of the Technical Integration Office and a campaign structure to more effectively and efficiently integrate and manage research and development activities.
- Demonstration of the Uranium Extraction (UREX)+3a separation process using high-burnup spent fuel discharged from the H.B. Robinson reactor.
- Demonstration of the UREX +3b separation process using spent fuel discharged from the Dresden reactor in the Coupled End to End Demonstration.
- Initiation of the irradiation of the second series of metal and oxide experimental transmutation fuel tests in the Advanced Test Reactor.
- Fabrication of lanthanide-bearing urania pellets used to study the effects of lanthanide elements on fuel development.
- Initiation of the FUTURIX-FTA irradiation in the French Phénix sodium fast reactor. This test has been in development since 2004 and is the first opportunity for U.S. researchers to irradiate transuranic-bearing reactor fuel in a fast spectrum reactor.
- An update to the Advanced Fuel Cycle Cost Basis Report. This report includes an evaluation of nuclear power's economic competitiveness compared to other baseline generating technologies and presents new data on advanced reactor and fuel cycle facility capital and operational costs.

- Development of a new oxide fuel sintering technique using microwaves. This work demonstrated that microwave sintering is significantly more energy efficient than sintering in a conventional oven.

Research performed under the program during 2007 directly supports major milestones that are coming due over the next several years. These milestones include a Secretarial decision on the future direction of GNEP, expected to be made during 2008, and a decision on the need for a second geologic repository expected to be made before 2010.



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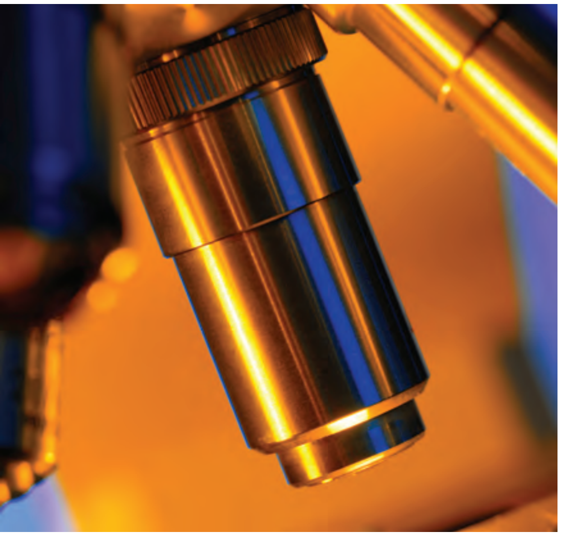

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Acronyms

AFCI Advanced Fuel Cycle Initiative

DOE Department of Energy

EPACT Energy Policy Act of 2005

FPEX Fission Product Extraction

GNEP Global Nuclear Energy Partnership

MDD Modified Direct Denitration

MOX Mixed oxide

NPEX Neptunium Extraction

TALSPEAK Trivalent Actinide-Lanthanide Separations by Phosphorous reagent Extraction from Aqueous Complexes

TRUEX Transuranic Extraction

UREX+ Uranium Extraction Plus

VISION Verifiable Fuel Cycle Simulation

1.0 Introduction

This document is the second annual report developed by the Department of Energy (DOE), Office of Nuclear Energy, in response to requirements in the Energy Policy Act (EPACT) of 2005. Section 953 of the EPACT directs the Secretary of Energy, acting through the Assistant Secretary for Nuclear Energy, to:

> "… conduct an advanced fuel recycling technology research, development, and demonstration program to evaluate proliferation-resistant fuel recycling and transmutation technologies that minimize environmental and public health and safety impacts as an alternative to aqueous reprocessing technologies deployed as of the date of enactment of [the EPACT]…."

Furthermore, the EPACT requires the Secretary to:

> "… submit as part of the annual budget submission of the Department, a report on the activities of the program."

This report summarizes the activities and accomplishments of the Advanced Fuel Cycle Initiative and Global Nuclear Energy Partnership (AFCI/GNEP) for fiscal year 2007. A listing of the program's FY 2007 funding is provided in the table below.

Title	FY 2007 Funding
Separations	$31,996,797
Advanced Fuels Development	$20,684,780
Transmutation Engineering	$6,676,615
Systems Analysis	$5,752,571
Transmutation Education	$6,421,330
Technical Integration and International Coordination	$11,834,208
Technology Development	$22,075,483
Advanced Fuel Cycle Facility	$9,246,127
Consolidated Fuel Treatment Center	$8,641,500
Advanced Burner Reactor Support	$8,641,500
Total	**$131,970,911**

2.0 AFCI/GNEP Campaign Overview

The mission of AFCI is to develop fuel cycle technologies that will support the economic and sustained production of nuclear energy while minimizing waste and satisfying requirements for a controlled, proliferation-resistant nuclear materials management system. The program is supported by fuel cycle research performed at ten national laboratories, dozens of universities located across the country, and our international collaborators' laboratories.

GNEP is a related program announced during 2006. The partnership is an evolving strategy aimed at reducing global dependence on fossil fuels while providing safe, reliable, and abundant energy. The program is also aimed at fostering development of domestic and international expertise needed to deploy advanced nuclear technologies that reduce risks associated with waste disposal and nuclear proliferation.

Research supporting AFCI/GNEP has been organized into seven campaigns and two cross-cutting organizations (Fig. 1). The seven campaigns include separations technologies, advanced fuel development, systems analysis, advanced reactor design, waste form development, safeguard system development, and small reactor development. The two cross-cutting organizations provide support for modeling and simulation, and nuclear safety and regulatory activities. A campaign director has been assigned to lead each of the campaigns, and a technical integration office has been established to coordinate and integrate the campaigns.

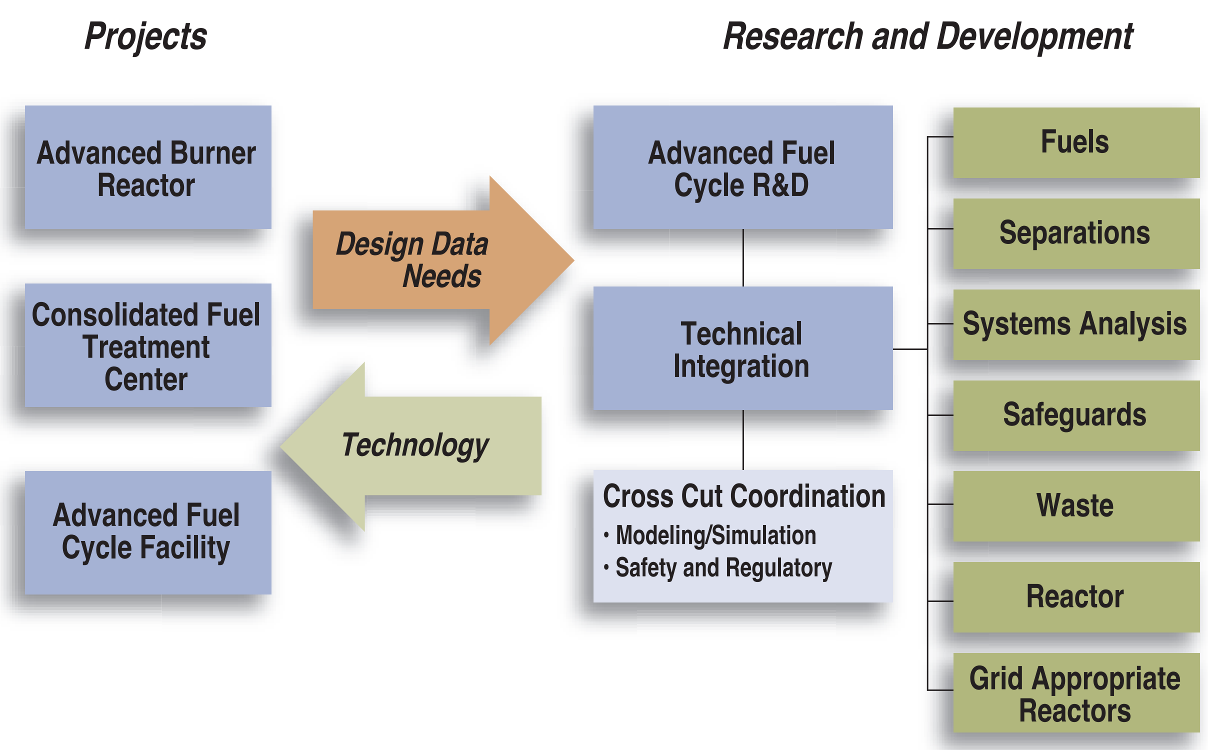


Figure 1. GNEP Organizational Structure

The Secretary of Energy is expected to make a decision about the future direction of the AFCI/GNEP Program during 2008. A Programmatic Environmental Impact Statement that discusses potential impacts of the program, including impacts of the design, siting, construction, operation, and eventual decontamination and decommissioning of an Advanced Fuel Cycle Research Facility, is under development to support this decision.

The following sections present a discussion of FY 2007 accomplishments for the main AFCI Program elements. These elements include Systems Analysis, Separations Technology Development, Advanced Fuels Development, Transmutation Engineering, Transmutation Education, and Fuel Cycle Facilities.

3.0 Systems Analysis

The goal of the Systems Analysis campaign is to perform integrating studies that enable a requirements-driven process for the AFCI program. The requirements identified by Systems Analysis research help to set boundaries and objectives for the program's fuel cycle research. Major accomplishments in 2007 include the following.

The Advanced Fuel Cycle Cost Basis Report was updated using Systems Analysis techniques during 2007. The update was a continuation of work performed during 2006 and used improved cost data based on more than 150 new references. The report includes an evaluation of nuclear power's economic competitiveness compared to other baseline generating technologies and presents new data on advanced reactor and fuel cycle facility capital and operational costs. It evaluates impacts associated with the rising costs of fuel cycle front-end operations, such as uranium mining, conversion, enrichment, and fuel fabrication, and presents estimates of probabilities associated with the fuel cycle's major cost components. The report also analyzes uncertainties to determine the range of costs for fuel cycle facilities that would have to be achieved to make a closed fuel cycle economically competitive.

The fifth annual update to the Fuel Cycle Comparison Report was prepared. This report evaluates relative advantages and disadvantages associated with various fuel cycle alternatives, such as near term development of fast reactors, versus continued reliance on light water reactors. The update included analysis of dual-tier fuel management involving use of recycled plutonium in thermal reactors followed by actinide consumption in fast reactors. A Thermal Recycle Benefits Report was also developed to examine potential advantages of recycling fuel using light water reactors in conjunction with, or in place of, fast reactor recycling.

Several updates to the Verifiable Fuel Cycle Simulation (VISION) code were issued during 2007. The code is a dynamic nuclear energy systems code capable of modeling fuel cycle scenarios using multiple reactor and fuel combinations. VISION can be used to track the mass flows of uranium, plutonium, minor actinides, and fission products through the fuel cycle while accounting for radioactive decay. The code updates included addition of variable fuel burnup analysis, user-defined reactor closure schedules, improved fast reactor deployment logic, and user-defined energy demand growth rates. The code was also extended to include development of dynamic cost profiles and improved uncertainty analysis. The code was distributed to a wide range of national laboratories and universities and a Web site was established to facilitate collaboration during future code updates.

The goal of the Systems Analysis campaign is to perform integrating studies that enable a requirements-driven process for the AFCI program.

4.0 Separations Technology Development

The goal of Separations research is to develop advanced aqueous and electrochemical separations technologies capable of treating the existing and projected inventory of spent nuclear fuel and fast reactor recycle fuel in a safe, efficient, and proliferation-resistant manner. The AFCI Program continued developing and refining two areas of fuel separations technology during 2007: advanced aqueous processing and electrochemical processing. Advanced aqueous separation methods can be used to efficiently process spent light water reactor fuel while the electrochemical process may be better suited for processing fuels designed for advanced reactors.

The program's advanced aqueous processing research continued to focus on development of the Uranium Extraction Plus (UREX+) suite of processes (Fig. 2). The UREX processes are enhanced separation methods that allow extraction of uranium, transuranic elements, and fission products from light water reactor spent fuel without the separation of pure plutonium, a potential weapons material. The goals for the UREX process are to recover uranium from spent fuel so it can be recycled, separate transuranic elements such as plutonium, americium, and curium for possible reuse in advanced fuels, and separate technetium, iodine, and other fission products for disposal in a stable waste form.

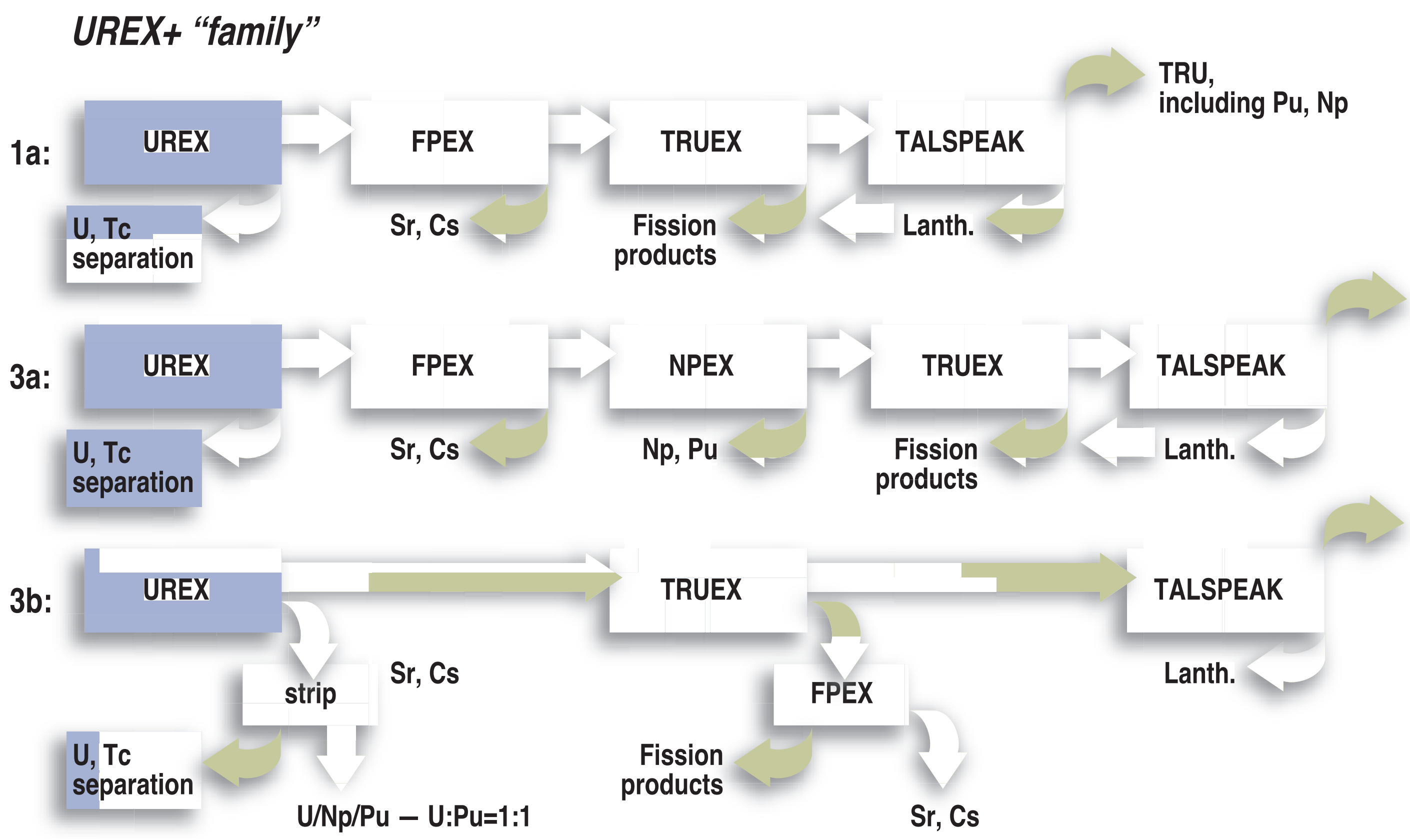


Figure 2. Representative Examples of the UREX+ Family of Separation Processes

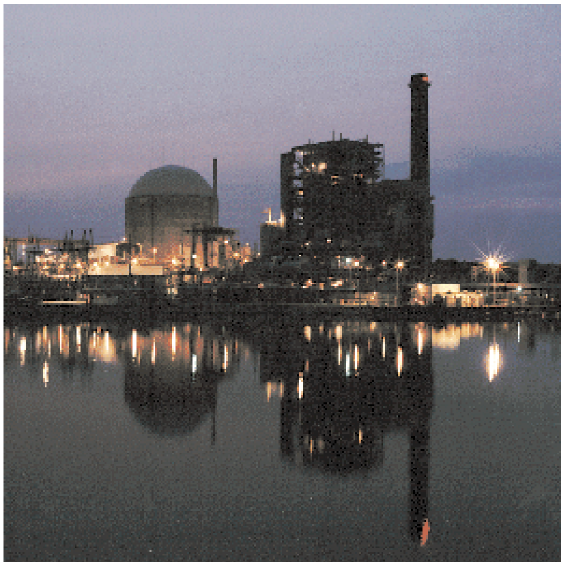
Electrochemical processing relies on nonaqueous reactions to separate spent metal or oxide fuel into various components. The components include an actinide stream that can be recycled to make new fuel and a fission product stream that can be stabilized and disposed of as waste. The process continued to be used during 2007 to treat more than 100 kilograms of spent fuel from the Experimental Breeder Reactor II.

4.1 Advanced Aqueous Processing

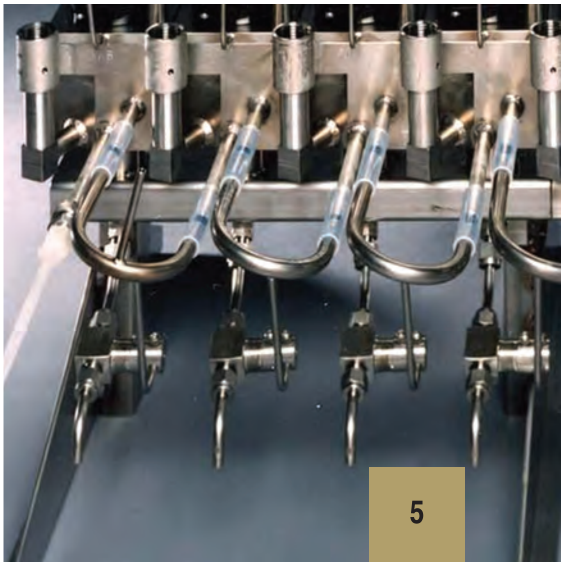
Experiments completed during 2007 demonstrated that the UREX+3a separation process can be used to efficiently process light water reactor fuel. The demonstration used high-burnup spent fuel from the H.B. Robinson reactor in South Carolina and process flowsheets that were updated from testing completed during 2006. The process demonstration began in June 2007 with an integrated test of the first three UREX segments [Uranium Extraction, Fission Product Extraction (FPEX), and Neptunium Extraction (NPEX)]. All three processes were run successfully under design conditions. The fourth segment, Transuranic Extraction (TRUEX), was demonstrated during July. This demonstration proved transition metal fission products remaining in the NPEX raffinate could be successfully removed under design conditions. Three multi-stage tests of the TALSPEAK (Trivalent Actinide-Lanthanide Separations by Phosphorous reagent Extraction from Aqueous Complexes) process were also completed. These tests indicated that the process can separate essentially all lanthanide isotopes from transuranic isotopes at moderate flow rates, and an acceptable amount of separation can be achieved even at high flow rates. A report on the UREX+3a process demonstration was developed and issued during September.

Detailed research on the various components of the UREX+3a process was also completed during the year. Testing on several calixarene compounds was completed to help improve the FPEX process, and one of the compounds was selected for development. Calixarenes are organic molecules that can be used to capture cesium and strontium isotopes so the isotopes can be separated from the rest of the UREX+3a waste. A process for directly precipitating a solid uranium peroxide compound was also developed. The process separated more than 90 percent of uranium from solution and produced a solid that was essentially free from technetium contamination. The approach shows promise for treatment of UREX strip solutions without reliance on ion exchange resins.

A number of design improvements were developed and implemented for contactors used to support the UREX+ processes (Fig. 3). Contactors are devices used to mix aqueous solutions containing dissolved spent fuel components with solvents that separate the components into different streams. The contactor work included design changes needed to adapt a 2 centimeter diameter contactor for use in a shielded process cell and mass transfer testing of a 12.5 centimeter centrifugal contactor. The testing proved mass transfer efficiencies of greater than 98 percent could be achieved using the larger contactor. A design for a remotely operated contactor was also developed, and the contactor was incorporated into a three-pack assembly that was successfully tested and used for procedure development.



Above. Robinson reactor in South Carolina. Below. Detail of Centrifugal Contractor.



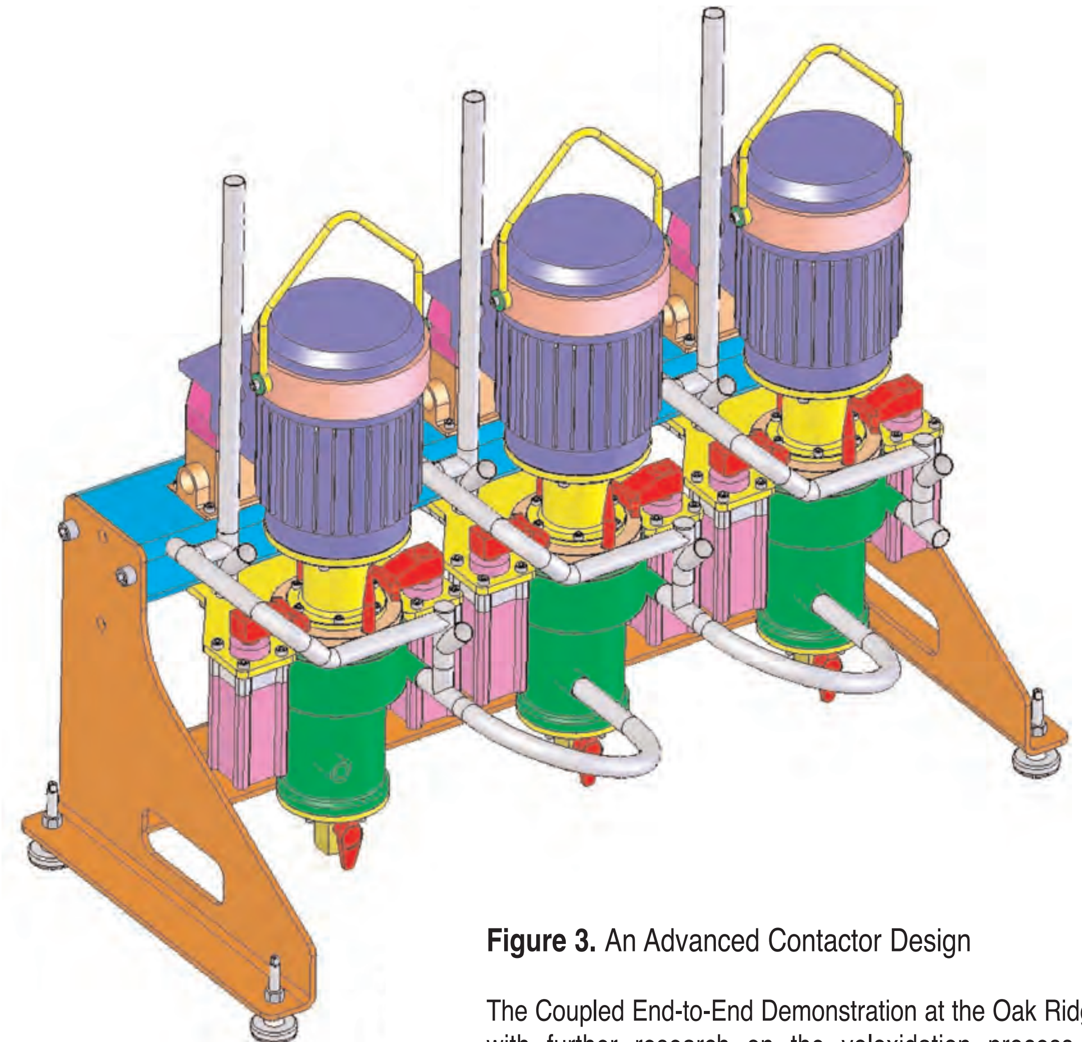
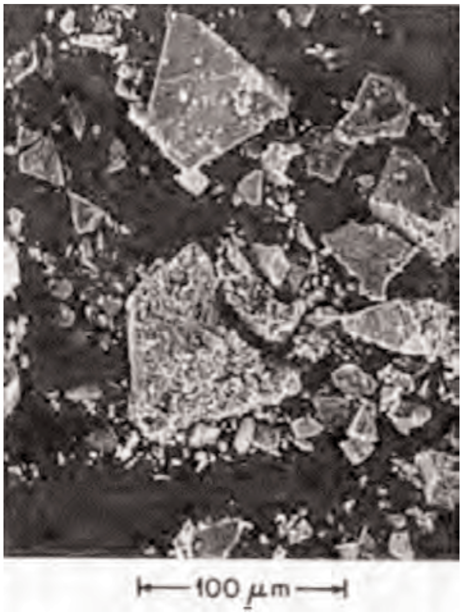


Figure 3. An Advanced Contactor Design

The Coupled End-to-End Demonstration at the Oak Ridge National Laboratory continued with further research on the voloxidation process and UREX+3b demonstration. Voloxidation is a head-end processing method that can be used to remove fuel from its cladding. The process may also improve fuel dissolution efficiency by reducing the sizes of particles that have to be treated, and it may allow removal and collection of volatile radionuclides prior to downstream treatment. The program's voloxidation research included processing of nearly five kilograms of Dresden commercial reactor spent nuclear fuel to demonstrate that the fuel could be efficiently released from its cladding. The unclad fuel was then processed through a box furnace to analyze oxidation efficiencies. Analysis of the off-gas traps used during the heating showed tritium and iodine were released from the fuel as expected and proved that the gases could be effectively collected for treatment. Following voloxidation, the UREX+3b flowsheet was successfully demonstrated.

Progress has been made on the development of a modified direct denitration (MDD) process (Fig. 4). This process holds promise for producing oxide powders ready for fuel fabrication without milling or grinding. Oxide powders produced through traditional denitration have a glassy, crystalline structure that requires significant rework before fuel fabrication, whereas powders produced by MDD have characteristic high-surface area morphology that allows them to be directly pressed and sintered into fuel.



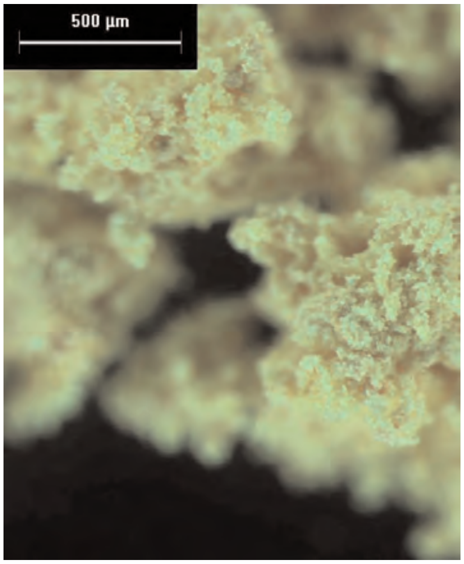


Figure 4. Comparison of oxide powders obtained from traditional direct denitration (left) to modified direct denitration (right).

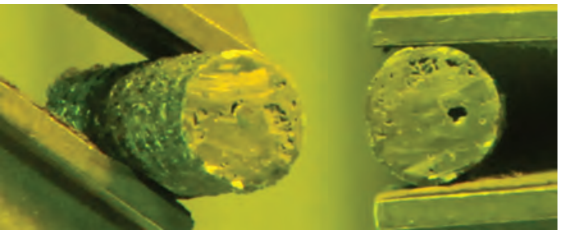
A significant amount of waste form research was also completed during 2007. The objective of this research was to develop and optimize methods for confining wastes in stable and durable configurations suitable for long-term storage. Product consistency tests were performed on two experimental waste forms; alumino-silicate glass and sintered clay ceramic. The tests supported development of 11 different types of glass that were fabricated for durability evaluation. Testing of bentonite clay samples loaded with cesium, strontium, barium, and rubidium nitrates proved that cesium would not volatilize from sintered or unsintered clay, and leachability testing of the clay ceramics was begun to study how well the ceramics retain waste constituents. An alloy system was also identified that could be used to combine fuel cladding hulls, technetium metal, and undissolved solids into a monolithic waste form. Coupons of the alloy were fabricated and characterized to evaluate waste form homogeneity and constituent partitioning.

4.2 Electrochemical Processing

Improvements in electrochemical processing hardware were achieved during 2007. A prototype of a high-throughput electrorefiner for efficient recovery of uranium from spent nuclear fuel has been further developed. In the uranium electrorefiner a voltage is applied between a set of anode baskets, which contain the spent fuel, and cathodes, both of which are immersed in a LiCl-KCl-UCl3 molten salt electrolyte at 500ºC. Inside the anode baskets, uranium and other constituents of the spent fuel are electrochemically oxidized to form soluble metal chloride species that dissolve in the molten salt electrolyte. At the cathodes, only uranium ions are electrochemically reduced to uranium metal, which forms a deposit on the cathode. Having demonstrated highly efficient dissolution, electrotransport and deposition of the uranium under a wide range of conditions, tests are now concentrating on optimizing the collection and removal of the uranium electrodeposit

A prototype of a high-throughput electrorefiner for efficient recovery of uranium from spent nuclear fuel has been further developed.

from the system. The prototype unit incorporates a collection basket that can be removed without interrupting the electrorefiner current thereby maximizing efficiency of the unit and supplying a semi-continuous output of high-purity uranium product.



Additional improvements to electrochemical processing hardware include installing equipment to provide more accurate measurement of electrolytic reduction system voltages. Accurate voltage measurements will provide a more effective means of monitoring future liquid cadmium cathode tests. Design requirements were also developed for an electrolytic reduction system for treating oxide feed material with high transuranic content. Material that is compatible with high transuranic content metal was acquired and tested in preparation for constructing the new system's cathode basket.

Research activities also focused on evaluating process performance. For example, plutonium was successfully oxidized into a molten salt containing uranium chloride, and experiments were performed to define the reduction and oxidation chemistry of plutonium and uranium chlorides. The experimental results were used to develop a model of actinide chloride concentrations needed to obtain a given plutonium to uranium ratio in the separated product. Experiments were also performed on oxide feed material containing rare earth fission products to determine whether the rare earth components can be reduced to metal, whether they form oxychlorides soluble in molten salt, or whether they remain in the electrorefiner basket as oxides.

Additionally, a series of four electrolytic reduction experiments were conducted with spent light water reactor fuel from Belgium Reactor 3. Approximately 200 grams of material were successfully reduced during the experiments, and analysis of the reduced material clearly identified expected diffusion and accumulation of cesium, barium, strontium, rubidium, and telurium into the salt phase. No other noble metal or rare earth fission products were detected in the salt.

5.0 Advanced Fuels Development

The goal of the Advanced Fuels Research and Development activity is to develop, fabricate, and demonstrate transmutation fuels and targets using recycled spent nuclear fuel. Advanced fuels research focused on developing and optimizing methods for incorporating transuranics, such as plutonium and higher actinides, into fresh fuel. The research investigated new techniques that will enable actinides to be used for power generation rather than sending them to a repository for disposal. Fuel types that were investigated during 2007 included: mixed oxide (MOX) fuels, metal fuels and nitride fuels.

A campaign execution plan was finalized for transuranic fuels during the first half of the year. The plan will guide long-term fuel development and qualification efforts and will help minimize the time needed to make these fuels available for commercial use. The plan identifies high-priority laboratory and reactor irradiation studies that will increase technological readiness of the fuels while minimizing development costs.

Several important fuel development experiments and computational modeling studies were completed during 2007. The studies included fabrication of lanthanide-bearing urania pellets that were used to evaluate the effects of lanthanide elements on fuel behavior. The studies indicated that required fuel pellet densities can be achieved even with lanthanide carryover during the fuel powder production process.

An oxide stoichiometry model was also developed to refine the sintering temperatures and atmospheric conditions required to achieve desired oxygen to metal ratios in sintered fuel pellets. The model will be incorporated into studies of fuel powders that have high oxygen contents.

Transmission electron microscopy studies of advanced fuel cladding alloys, measurements of iron crystal hardening due to irradiation, and ductility testing of advanced steels containing tantalum were also completed during the year.

A significant amount of work associated with fuel fabrication and fuel material supply was completed. For example, a method for synthesizing uranium nitride using a reactive milling technique was successfully developed. The technique will be used to develop materials needed for future nitride fuel testing. Processing parameters associated with development of uranium/plutonium MOX fuel were also evaluated. The development studies included optimization of powder blending, reduction of additives needed to fabricate fuel pellets, and evaluation of techniques for maximizing the quality of fabricated fuel. The studies also included evaluation of materials that could be used as binders during the fuel fabrication process. Polyethylene glycol was identified as a potentially useful binding agent since it decomposes quickly during the sintering process but still produces pellets of acceptably high density.

The Advanced Fuel Cycle (AFC) -1 fuel test performed in DOE's Advanced Test Reactor at the Idaho National Laboratory was completed during the summer 2007, and an experiment summary report was issued during September. One important conclusion of the study is that the allowable linear heat generation rate for fuels used in future irradiation experiments can be safely increased without exceeding cladding temperature limits. The results of the experiment were incorporated into an analysis of heat generation rate as a function of Uranium-235 content for advanced fuels.

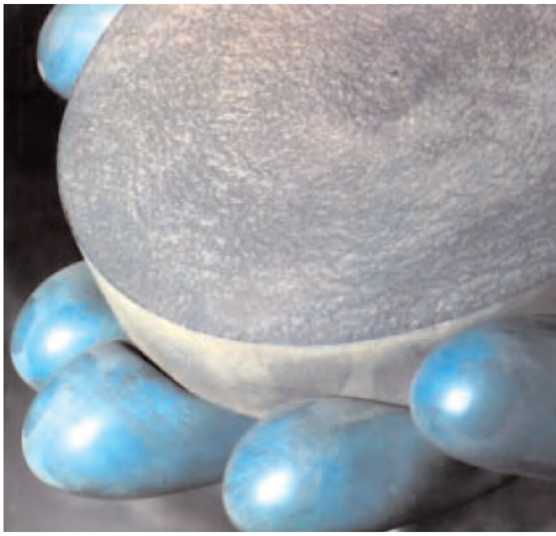


Figure 5. Advanced Fuel Fabrication Materials

Irradiation of the FUTURIX-FTA test package began during May 2007 in the Phénix test reactor located southwest of Grenoble, France. The objective of the experiment is to provide data on how fuels loaded with high concentrations of plutonium, neptunium, and americium perform in fast spectrum radiation fields. The experiment includes samples of oxide and metal fuels, and samples of nitride fuels may be added if approval is received from the French reactor safety authority. This test has been in development since 2004 and is the first opportunity for U.S. researchers to irradiate transuranic bearing reactor fuel compositions in a fast spectrum reactor.

Preparations for the AFC-2 fuel test were completed during September 2007. This test will include irradiation in the Advanced Test Reactor at the Idaho National Laboratory of multiple oxide and metal fuel assemblies between FYs 2008 and 2013. Test preparations included fabrication of multiple metal and oxide fuel assemblies, microstructural characterization of the test assemblies, and development of the test safety basis and procedures. Irradiation of the oxide fuel assemblies began in October 2007. Irradiation of the metal fuel assemblies is scheduled to begin in the first quarter of fiscal year 2009.

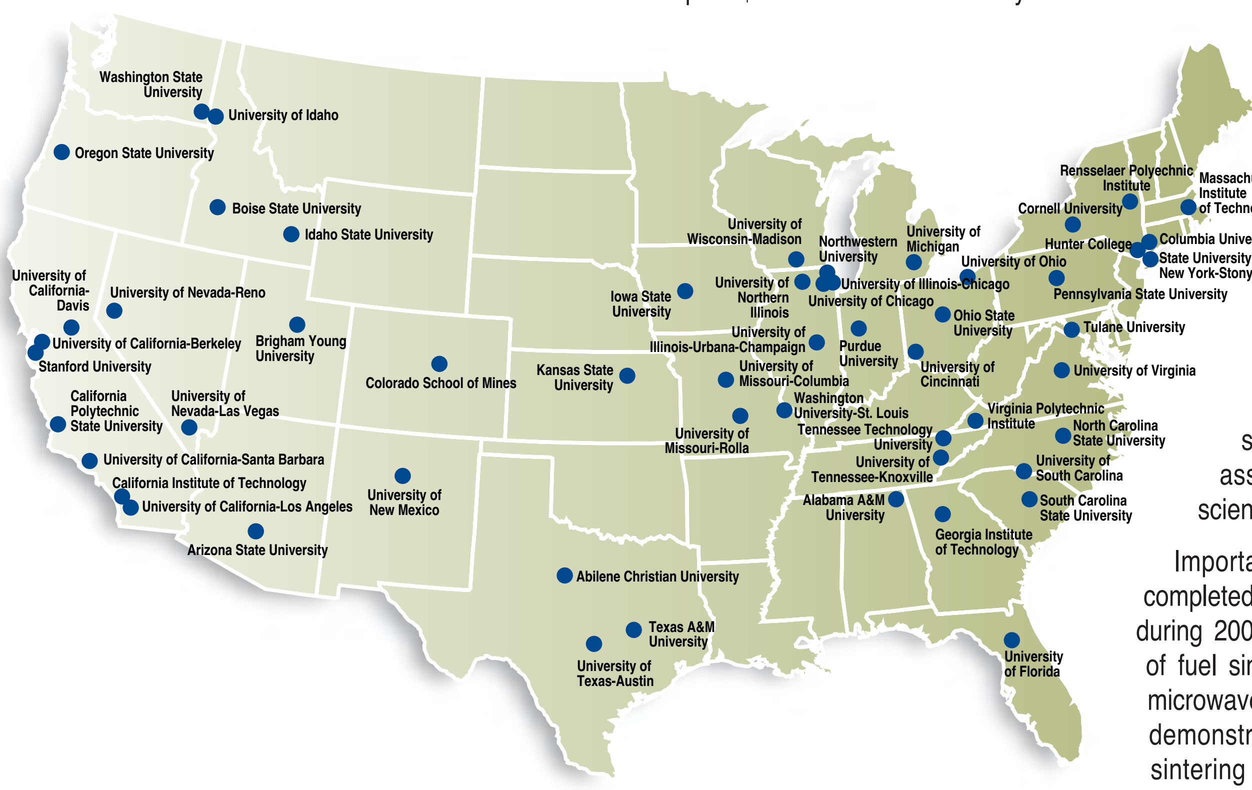
6.0 Transmutation Engineering

Transmutation Engineering research is focused on long-term research and development to reduce operational uncertainties, improve transmutation system performance, and reduce costs through development of advanced technologies. Transmutation engineering activities completed during 2007 focused on design and installation of equipment needed to perform advanced fuel development studies and continuation of reactor irradiation studies that support testing of advanced fuel materials (Fig. 5).

New post-irradiation examination equipment, which was designed and installed to support advanced fuel research, included a system for determining oxygen to metal ratios in fuel materials. The equipment also included a new furnace that allows fuel sintering atmospheres to be precisely controlled so that appropriate oxygen to metal ratios can be achieved. Data developed through use of the furnace indicates high oxygen to metal ratio feedstock produces fuel pellets with high physical integrity, high density, and high sinterability characteristics. A centrifugal caster was also set up and demonstrated using several test alloys. The time needed to melt and cast alloys using the equipment was reduced to less than two minutes. Other equipment designed, tested, and installed during the year included an optical system for measuring thermal conductivity of irradiated fuel, analytical equipment used for characterization of fabricated oxide fuels, and a carbide tool to be used for cutting test specimens from irradiated materials.

7.0 Transmutation Education

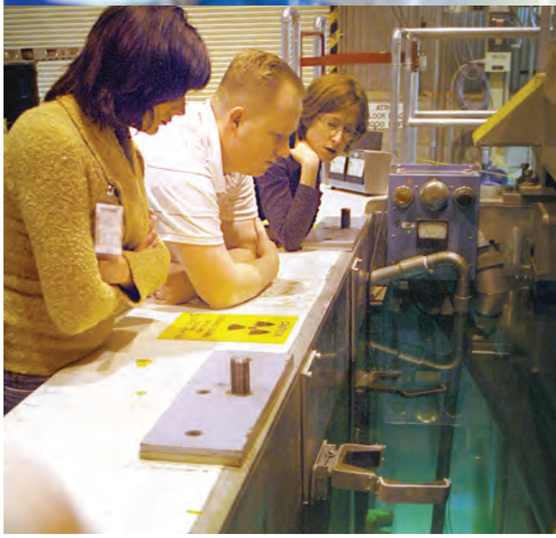
Figure 6. Universities Performing AFCI/GNEP Research



Nuclear Energy Research Initiative grants were issued to 11 teams that include 38 universities in 22 states (Fig. 6). The grants will provide funding of up to $30.7 million over three years to the research teams, and contributed to the $15.2 million that DOE awarded to universities during 2007. The Nuclear Energy Research Initiative is focused on development of advanced nuclear energy systems and state of the art research associated with nuclear science and technology.

Important AFCI research completed at several universities during 2007 included development of fuel sintering techniques using microwave applicators. This work demonstrated that microwave sintering is significantly more energy efficient than sintering in a conventional oven. For example, at Virginia Tech, the microwave sintering achieved the same pellet density after 45 minutes of heating at 950 °C as heating in a conventional oven achieved after 60 minutes at 1,400 °C.

Experiments were also completed at UNLV to evaluate optical fluorescence of uranyl ions. This work was performed to support development of sensors that can detect fissionable materials in liquids. The experiments included analysis of the degree to which iron could quench optical fluorescence of uranyl ions in the aqueous phase.



Other AFCI nuclear research accomplishments achieved by university programs included:

- A detailed structural and chemical model of silicon carbide crystals was developed using photoemission data collected at Lawrence Livermore National Laboratory. (University of Nevada – Las Vegas)
- Research on the use of positron annihilation to nondestructively identify material defects continued. (Idaho State University)
- The Equilibrium Operation Fuel Cycle Model was developed to provide a simple calculation of key fuel cycle parameters (i.e. economics, heavy metal inventory, etc.) using an equilibrium operation approximation for a nuclear park scenario consisting of two reactor types. (University of Michigan)
- Rate-controlled sintering experiments using composite materials were performed to identify conditions that minimize cracking and maximize density. (University of Florida)
- A test facility that simulates heat transfer from spent light water reactor fuel to the interior of transport and storage casks is under development. Test results will be used to benchmark computer codes that predict spent fuel temperatures in casks. (University of Nevada – Reno)
- Mini-photonuclear detectors were tested using U-238 under bremsstrahlung radiation. (Idaho State University)
- Uranium nitride with 97 percent purity was synthesized using zirconium metal as an oxygen trap. (University of Nevada – Las Vegas)
- Microstructures of irradiated and unirradiated zinc nitride and zinc carbide were examined to determine their behavior as the matrix of advanced nuclear fuels. (University of Wisconsin)
- Calculations of decay heat generation from residual deep burn isotopes were developed. (University of Nevada – Las Vegas)
- Three large-scale fire tests of rail casks were completed to collect data for modeling. (University of Nevada – Reno)

The AFCI/GNEP fellowship program continued with the awarding of eight Masters Degree fellowships. Thesis topics of these fellows will be of direct benefit to AFCI.

8.0 Fuel Cycle Facilities

Development of conceptual designs for advanced fuel cycle facilities continued during 2007. The facilities currently under consideration are:

- Advanced Recycling Reactor – A fast neutron spectrum reactor that would be capable of producing power while converting long-lived radioactive elements (e.g., plutonium and other transuranics) into shorter lived elements.
- Nuclear Fuel Recycling Center – A facility that would separate spent nuclear fuel into reusable and nonreusable components. The facility would also be used for fabrication of fuels that could be used in the advanced recycling reactor.
- Advanced Fuel Cycle Research Facility – A facility that would support research and development related to separation and fabrication of fast reactor transmutation fuels.

DOE awarded contracts to four industry teams that will develop studies associated with deployment of the advanced fuel cycle facilities. These cooperative agreements will engage the world's most capable nuclear technology companies in developing innovative plans for designing, building, and operating the facilities. Under the agreements, the teams will develop conceptual design studies, technology development roadmaps, business plans, and communication strategies while working closely with DOE's researchers. The agreements will combine the strengths of the nuclear industry's public and private sectors to develop innovative and cost-effective plans for demonstrating and deploying advanced nuclear technologies.

8.1 Advanced Recycling Reactor

Fast reactor research continued to be a high priority for the AFCI Program's technology development efforts. During the year, researchers built on past experimental work to develop completely new conceptual designs (Fig. 7) for fast reactors that could be powered by metal or oxide fuels. Important performance parameters considered during development of the designs included use of a small core size to reduce construction costs, use of a long refueling cycle to minimize reactor down time, and use of a low conversion ratio so the reactors could efficiently destroy transuranic isotopes while generating power. The designs illustrate the feasibility of building a 1,000 megawatt advanced reactor using various types of advanced fuels.

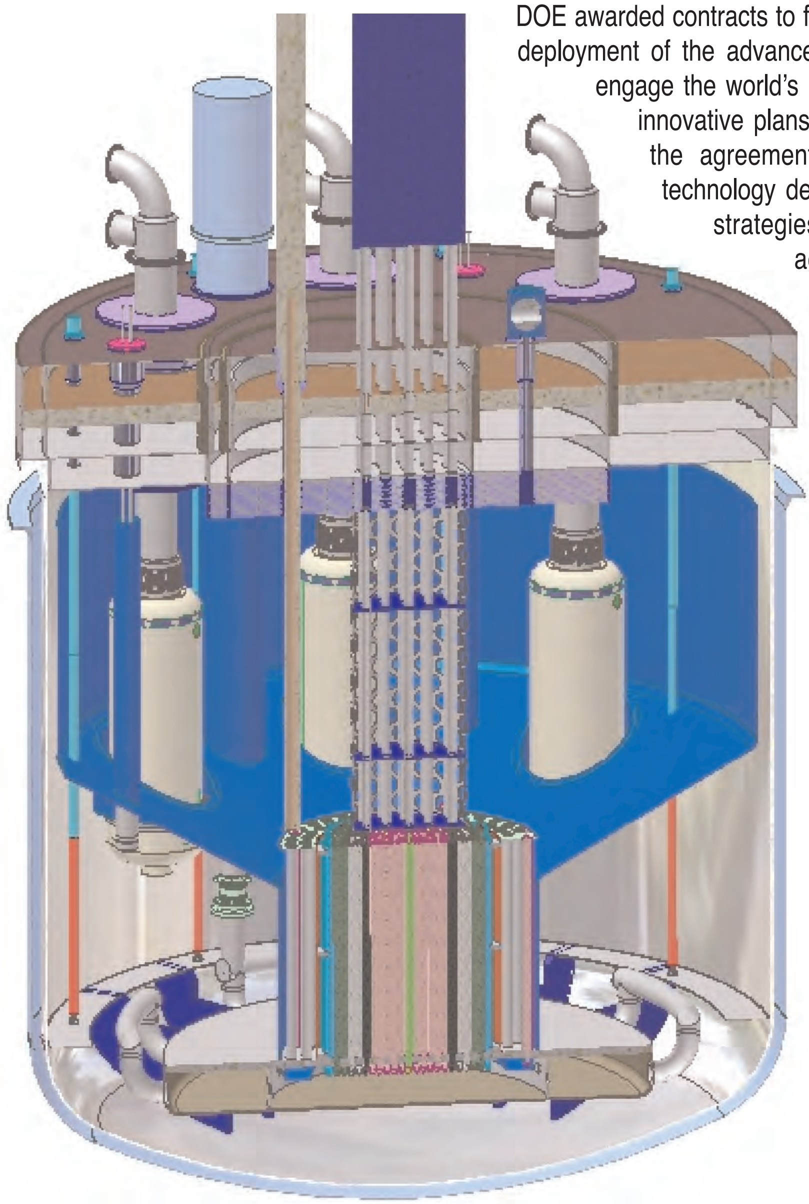


Figure 7. An Advanced Reactor Concept

The design effort also supported development of a comprehensive analysis of technologies that need to be developed to make fast reactors commercially viable. An important gap identified by this analysis is the need for domestic sodium testing facilities that can be used to investigate and demonstrate advanced reactor technologies. The design effort also produced estimates of advanced reactor construction durations as a function of gross plant power, estimates of isotopic masses and spent fuel decay heat that would be produced by metal and oxide fuel cores, and evidence that advanced reactor structural materials could last for well over 60 years when maintained in a clean sodium environment.

8.2 Nuclear Fuel Recycling Center

A conceptual design for a large-scale recycling center was developed as part of the program's Engineering Alternatives Study effort. The design team held comprehensive reviews of the 30 percent, 60 percent, and 90 percent design packages during the year and issued nine reports detailing various aspects of the facility's conceptual design. Plans were also developed for producing conceptual designs of a smaller scale recycling facility that could be used as a basis for evaluating the implementability of proposals included in the industry team deliverables.

8.3 Advanced Fuel Cycle Research Facility

Functional and operational requirements and conceptual designs for the Advanced Fuel Cycle Research Facility were developed during 2007. These designs and facility requirements supported development of the GNEP Programmatic Environmental Impact Statement and helped lay the foundation for upcoming facility designs. A comprehensive quality assurance program was also established to ensure current and future design work will be able to support eventual submission of a facility operations license application.

9.0 Summary

A significant amount of research supporting each of the major AFCI Program components was completed during 2007. This work has set the stage for implementation of major new advanced fuel tests, separations process demonstrations, facility designs, and modeling and simulation activities. The research also supported development of the next generation of nuclear engineers and scientists who are currently being educated at universities throughout the United States, and it will support large-scale collaboration between the world's most innovative nuclear technology companies and the country's premier nuclear research laboratories.

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